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Electrostatic Properties of Plastic Trays Used for Packaging 20mm Ammunition

Gunars Bajinskis, Horace Billon
and Jim Quinn

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Weapons Systems Division
Aeronautical and Maritime Research Laboratory

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ABSTRACT

Electrostatic hazards associated with handling RAAF M55 (AUST) 20 mm TP ammunition packaged in ammunition boxes using new plastic separator trays have been analysed. Moulded plastic trays have been introduced into the ammunition box to replace cardboard cylinders for individual rounds. Tests have been carried out to determine the electrostatic suitability of the tray when used with sensitive electrically initiated ammunition. The M52A3B1 conducting composition initiator used for the round has a no-fire threshold energy significantly below levels that tests show can be accumulated from electrostatic effects.

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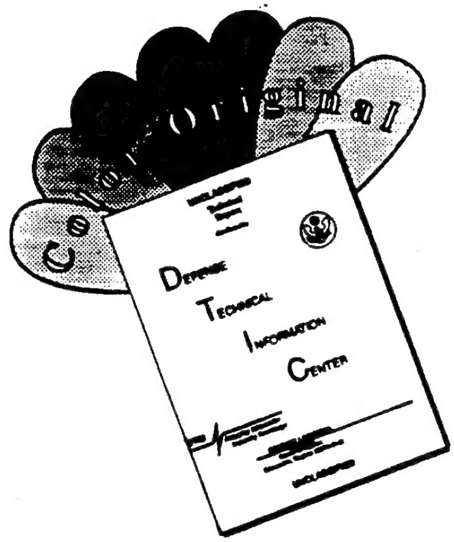

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Electrostatic Properties of Plastic Trays Used for Packaging 20 mm Ammunition

Executive Summary

The RAAF has recently introduced plastic separator trays for packaging 20 mm M55 (AUST) TP ammunition. These trays are meant to replace the cardboard cylinders that had originally been used to package individual rounds. The 20 mm ammunition in question is used in the M61A1 cannon on the F/A-18 aircraft, is electrically initiated and is extremely sensitive to initiation by electrostatic discharge.

Concerns have been expressed by RAAF personnel regarding the safety of the new trays and Explosive Ordnance Logistics Management Squadron (EOLMSQN) requested that the Australian Ordnance Council (AOC) evaluate the electrostatic characteristics of the trays. This paper presents the results of an AMRL investigation undertaken on behalf of the AOC.

The investigation was conducted at Number 1 Central Ammunition Depot (1CAMD) Orchard Hills, New South Wales. RAAF personnel performed a number of tasks so that handling procedures associated with the trays could be evaluated. In particular, it was found that a large amount of electrical energy could be accumulated on certain objects in the vicinity of the trays. The accumulated energy often greatly exceeded the energy necessary to initiate the 20 mm round.

As a result of the investigation it was concluded that the plastic trays introduce an electrostatic hazard into the handling of M55 20 mm ammunition. It is therefore recommended that the plastic trays be replaced or modified. Since a large number of 20 mm rounds has already been packed using the new trays, it is recommended that a procedure be devised to enable these rounds to be safely repacked.

Authors

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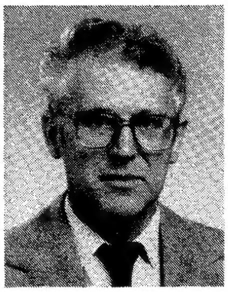

Gunars Bajinskis joined AMRL in 1961 and was responsible for electrical evaluation of components and materials in the Type Approval Section. In 1967 he was requested to set up an electrostatics investigations unit to serve Defence and industry. Since then his work has covered a wide range of electrostatic topics in manufacturing, clothing, explosives safety, munitions handling and related accident investigations. He has also investigated sealant problems in the fuel tanks of F-111 aircraft and played a major part in the local development and manufacture of new high power HF antennas for the Navy. His current work as Senior Technical Officer involves electrostatic consultancy to the Services and to Australian Defence Industries.

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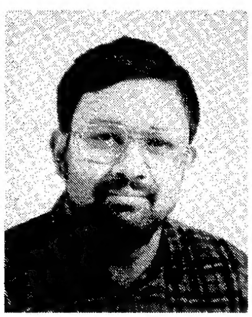

Horace Billon graduated from Royal Melbourne Institute of Technology with a BSc in Applied Physics. He also has a Graduate Diploma in Mathematical Methods from Royal Melbourne Institute of Technology. After working in the RAAF Quality Assurance Laboratories at Highett he joined AMRL in 1986. He works in the Weapons Systems Division, and his primary areas of interest are explosives rheology and electrostatics.

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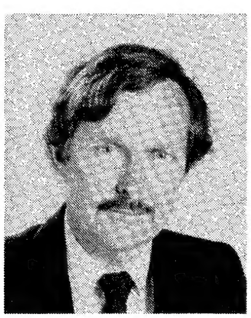

Jim Quinn obtained his BAppSc(Applied Physics) at the Royal Melbourne Institute of Technology in 1973 and is a Member of the Australian Institute of Physics. He joined the Materials Research Laboratory (now AMRL) in 1969 and has been involved in X-ray crystallography, dimensional metrology, X-radiography, image analysis, pattern recognition and simulation methods for electromagnetic pulse effects on electronic systems. In the weapons systems area he has worked on the problems associated with the introduction of software controlled technology into the safety and arming units of fuzes for explosives ordnance. More recently he has assumed responsibility for protecting defence personnel and materiel from electrostatic discharge, lightning and related effects.

Contents

1. Background

M55 (AUST) 20 mm TP ammunition manufactured in Australia by Australian Defence Industries (ADI) is used in the M61A1 (Vulcan) cannon on board the F/A-18 aircraft. Previously the rounds were delivered in boxes with each projectile covered by a waxed cardboard cylinder. An illustration comparing the two packaging methods is shown in Figure 1. In 1992, ADI was authorised to pack ammunition boxes with the rounds separated by clear moulded plastic trays [1]. The trays consist of a thin clear plastic moulded to fit the outline of each individual round providing it with good surface protection and efficient use of packing volume.

The M55 round is initiated by a M52A3B1 conducting composition (CC) primer. The electrostatic discharge (ESD) "no-fire energy threshold" (NFT) for the M52A3B1 has been determined [2] as 17 μJ for human ESD and 2 μJ for ESD from conducting objects with no added resistance [4]. In all facilities where explosive ordnance fitted with electro-explosive devices (EEDs) such as CC caps are handled, precautions must be observed to prevent hazards due to the accumulation of electrostatic charge [3]. One such precaution is the exclusion of electrically insulating plastic material from areas with electrostatically sensitive explosive initiators and equipment [3]. Concerns were voiced by RAAF personnel handling M55 ammunition regarding the safety of the plastic trays. Explosive Ordnance Logistics Management Squadron (EOLMSQN) subsequently requested the Australian Ordnance Council to evaluate the electrostatic characteristics of the trays.

This paper presents the results of the investigation undertaken on behalf of the Australian Ordnance Council.

2. Overview of Procedures

A series of measurements was carried out on personnel and equipment at the Number 1 Central Ammunition Depot (1CAMD) Orchard Hills, New South Wales. RAAF ammunition handlers performed a number of tasks on the 20 mm rounds so that the handling procedures could be evaluated. Subsequently a program of measurements was designed and coordinated with RAAF personnel.

Handling of M55 ammunition is performed in a bay where some electrostatic protection methods have been implemented. The bench has a copper surface which has a visible earth connection in the form of a cable and connector to an installed earth system. An antistatic floor system manufactured by the Tarkett Company has been installed. Each operator wore standard issue General Purpose (GP) boots with the added electrostatic precaution of a legstat over one boot. A legstat is a device strapped over footwear and around the leg of the wearer; it has an electrical connection from the leg to a conducting material which touches the floor. A permanent electrostatic footwear test meter is provided in the bay to measure body to ground resistance. A touch panel is provided to earth personnel in the room and signs are posted around the bay instructing personnel to earth themselves every five minutes.

A filled ammunition box contains 250 rounds weighing approximately 78 kg. Handling is generally carried out by a team of at least two personnel because of the weight involved. To empty the ammunition box the handlers place the full container upside down so that the lid rests on the copper topped table. The latches on either side of the box are then released to free the box from the lid. The box is then lifted up over the ammunition as shown in Figure 2. The ammunition retains its packing configuration after the box body is removed by virtue of the moulded packing trays. The rounds in each layer are oriented in the same direction and each layer holds alternatively twelve and thirteen rounds. A close packing configuration for successive layers is achieved by reversing the orientation of each layer, i.e. by placing the narrower projectile of the upper tray above the space between the broader cartridge cases in the layer below. The stack of ammunition in this form is acceptably stable when resting in the moulded plastic trays. The ammunition is removed from the stack one layer at a time as shown in Figure 3.

3. Measurements

3.1 Operator Body to Ground Resistance

A series of measurements was made to determine the operator body to ground resistance of operators without legstats. Resistance was measured between a hand held electrode and a metal plate on which the test subject stood. All available operators were tested as well as AMRL personnel. The resistances for the GP boots as worn by the 1CAMD personnel fall into a range (3×10^7 to 2×10^8 ohm) which provides acceptable dissipation to ground of electrostatic charge generated on the wearer. The footwear worn by AMRL staff in Test 8 is provided as an example of footwear which provides inadequate antistatic protection.

Table 1: Body to ground resistance of operators and other staff

Test	Test subject		Footwear	Resistance (ohm)
1.	1.	1CAMD Staff	GP boots	$2 \text{ X } 10^8$
2.	2.		"	8×10^7
3.	3.		"	2×10^8
4.	4.		"	3×10^7
5.	5.		"	4×10^7
6.	1.	AMRL staff	Antistatic shoes	1.5×10^6
7.	2.	"	Rubber soled shoes	$6. \times 10^8$
8.	3.	"	Rubber soled shoes	3×10^{11}

3.2 Electrostatic Charge Effects for Seated Operators and Incidental Plastic Trays on the Floor

Loose insulating objects can cause a hazard in electrostatically sensitive areas. As an illustration, the electric energy generated on an insulated person while rising from a stool was measured. A wooden stool located in the packing bay was used in this test. In the measurements an operator was seated on the stool with both feet resting on a plastic tray removed from a 20 mm round packing box. This represents the case where inadvertent insulation from earth is caused by the tray. The operator was connected to an electrostatic voltmeter which indicated the peak potential when the operator rose from the stool. While standing, the capacitance of the operator was determined and the generated energy calculated. One member of staff tested at 1CAMD was wearing a Disruptive Pattern Combat Uniform (DPCU). The measured and calculated values are shown in Table 2. The garments worn by an AMRL staff member in Test 5 is provided as an example of inadequate antistatic protection.

Table 2: Electrostatic energy on an operator while rising from a stool while standing on plastic trays.

Test	Test Subject	Garments Worn	Capacitance (pF)	Potential (V)	Energy (μJ)
1	1CAMD staff	Work clothes	250	50	0.3
2	"	"	190	100	1.0
3	"	DPCU	150	<50	<0.3
4	AMRL staff	Street garments	100	140	1.0
5	"	"	120	2500	380

3.3 Electrostatic Charging of Rounds by a Protective Visor

It was noted that a clear plastic visor was available in the packing bay for face protection during the handling of ammunition. A test was devised to illustrate the effect of a person wearing a charged visor bending over a round. A 20 mm round was placed vertically on a plastic tray and its capacitance measured as 20 pF. The visor was rubbed with a cotton cloth and brought near the round. A peak potential of 10 kV was measured which corresponds to an electrical energy of 1000 μJ.

3.4 Electrostatic Charging of Rounds on a Plastic Tray

Moving objects along a surface and separation of an object from a surface typically produces an electrostatic charge. Three tests were carried out which simulate the actions an operator might carry out with the plastic trays. In the first test a number of inert rounds was placed on a plastic tray and moved along the bench surface. In the second test an operator held the tray at both ends with bare hands and lifted it off the bench. In the third test the rounds were allowed to roll together after being lifted. The capacitance and potential of the rounds were measured at each stage of the test and the energy calculated. The values are given in Table 3.

Table 3: Electrostatic charging of rounds on a plastic tray

Test	Test Conditions	Capacitance (pF)	Potential (V)	Energy (μJ)
1.	Tray and rounds slid along the bench	40	50	0.05
2.	As above but lifted up	20	1500	23
3.	As for 2 but rounds allowed to roll together	24	1500	27

3.5 Electrostatic Charge Accumulation on the Metal Box from Charged Plastic Trays

This test was devised to measure the energy on a conducting object, in this case the ammunition box, with electrostatic charge acquired from plastic trays that had been rubbed against the bench top.

An empty ammunition box was located on a plastic tray lying on the bench surface. The capacitance of the box to the copper table top was 130 pF.

A number of plastic trays was rubbed against the bench surface and the trays were then deposited into the ammunition box. The energy on the box was calculated and is given in Table 4.

Table 4: Electrostatic charge accumulated on an ammunition box from charged trays

Test	Number of Trays Placed in the Box	Potential of Box (V)	Energy on Box (μJ)
1	1	2000	260
2	2	2500	406
3	1	2000	260
4	2	3000	585
5	3	5000	1625

3.6 Electrostatic Charge on Rounds After Removal from Ammunition Box

In the normal unpacking procedure the ammunition box is placed upside down on the bench surface. The box is then lifted off the rounds and removed leaving the stack of rounds on the lid. When the box is removed it brushes against the edges of the trays and electrostatic charges are developed on them. These electrostatic charges result in energy being induced on the stacked rounds. Highest charging was expected near the top of the stacked rounds due to the lower capacitance of these rounds to ground and the extra surface contact the trays near these rounds experience during removal of the ammunition box.

After removal of the ammunition box the potential and capacitance was measured on selected rounds. The values obtained indicated that the highest charging occurred in the top rows. The energy was calculated and the results are given in Table 5. Measurements were made for rounds having their initiators facing the observer for the top row and rounds in column five. The array of rounds is limited to those with the initiator facing the observer. The top left round (initiator facing observer) of the top row was taken as row 1, column 1. Row numbers increase down the stack while column numbers increase from left to right. A photograph of the stack is shown in Figure 4 to illustrate the position of rounds measured.

Table 5: Electrostatic charging of rounds in freestanding stack after removal of ammunition box

Test	Position of Round		Potential (V)	Capacitance (pF)	Energy (μJ)
	Row*	Column**			
1	1	1	354	n\a	n\a
2	1	2	1080	n\a	n\a
3	1	3	n\a	n\a	n\a
4	1	4	2100	n\a	n\a
5	1	5	1190	11	8
6	1	6	1530	n\a	n\a
7	1	7	1390	12	12
8	1	8	2070	n\a	n\a
9	1	9	2000	n\a	n\a
10	1	10	2650	10	35
11	1	11	2100	n\a	n\a
12	1	12	2000	n\a	n\a
13	1	13	1710	8	12
14	1	5	1190	11	8
15	2	5	680	n\a	n\a
16	3	5	n\a	n\a	n\a
17	4	5	250	n\a	n\a
18	5	5	140	22	0.2
19	6	5	30	n\a	n\a
20	7	5	n\a	n\a	n\a
21	8	5	40	31	0.02

* Rows are counted from the top layer, increasing in value for lower layers but limited to rounds with the initiator facing the observer.

** Columns are measured from left to right as seen in Figure 4.

4. Results and Discussion

4.1 Suitability of Packing Bay Facilities

The environment provided for handling the ammunition is satisfactory. The conducting table surfaces made from copper and the Tarkett antistatic floor surface in the bay were satisfactory for working on electrostatically sensitive devices.

4.2 Suitability of Handlers' Clothing

Garments and footwear worn by the RAAF operators provide satisfactory resistances for antistatic purposes. (para. 3.1).

4.3 Electrostatic Effects Due to Plastic Objects

Plastic packaging such as wrapping material or trays are often efficient generators of electrostatic charge when rubbed with a wide range of materials. If this charge is not dissipated then the charge can be accumulated on personnel and objects. Maintaining an electrostatic charge is achieved when a person or object is electrically isolated from earth. The plastic used for the trays is a good insulator and so the trays are capable of electrically isolating objects or personnel from electrical earth.

The electrostatic tests carried out on the ammunition box located on plastic trays resulted in the accumulation of electrical energies greater than 1600 μJ. In this test (para. 3.5) trays are acting as both generators and isolators. In normal handling rubbing and separation produce charges. Surplus trays can easily be used as a protective surface, or just inadvertently become wedged under equipment on the table surface. For this reason the Navy Ordnance Safety Manual [3] states that such material should not be introduced, or if it comes with the packaging it should be immediately removed from the bay.

Rubbing the trays on the table surface (para. 3.4) followed by separation generated electrostatic charge with an energy of 27 μJ on rounds located on the trays.

When the ammunition box was lifted off the stack (para. 3.6), the brushing effect of the box wall against the edges of the trays produced an electrostatic charge of 35 μJ energy on at least one round.

A plastic visor when rubbed with a tissue was able to induce an electrostatic charge (para. 3.3) with an energy of 1000 μJ on a round isolated from earth by being placed on a tray.

4.4 Electrostatic Discharge Hazards for Electroexplosive Devices

The threat to an EED posed by an ESD depends upon the energy deposited in the device and the sensitivity of the device. The sensitivity of the M52A3B1 initiator is quoted as an NFT of 17 μJ for an ESD from personnel [2]. In the equivalent circuit for a human a resistance of 330 ohm has been added. For discharges from conducting objects with no such added resistance the corresponding NFT [4] is 2 μJ. The NFT estimate is the value for which there is a 95% confidence that 0.1 % of the EEDs will function. The value is purposely low to afford a sufficient level of safety.

The electrostatic energies accumulated on personnel were below the personnel NFT for the M52A3B1 initiator for all 1CAMD staff. In one case a member of AMRL staff wearing inappropriate garments accumulated an electrostatic energy (para. 3.2) of 380 μJ. This presents a 7.5 % probability of firing the initiator if wholly discharged through the initiator [2].

The electrostatic energy of 1600 μJ accumulated on the ammunition box (para. 3.5), when related to the NFT of 2 μJ for conducting objects, presents a 100 % probability of activating the M52A3B1 initiator [4].

The 27 μJ electrostatic energy accumulated on the round situated on the tray (para 3.4) constitutes a 15 % probability of activating the initiator if discharged through the initiator to earth [4].

The 35 μJ electrostatic energy measured on one round after lifting the ammunition box from the stack (par. 3.6) represents a 26 % probability of activating the initiator if discharged through the initiator to earth [4].

The 1000 μJ electrostatic energy induced on the round by the plastic visor (para 3.3) represents a 100 % probability of activating the initiator if discharged through the initiator to earth [4].

5. Conclusions

The presence of the plastic trays introduces an electrostatic hazard into the handling of M55 20 mm ammunition.

The visor in the present condition is hazardous in the vicinity of the rounds.

6. Recommendations

It is recommended that the plastic tray be replaced or modified so that it no longer poses an electrostatic hazard. Consultation with AMRL for the replacement is available.

It is also recommended that a safe procedure be devised that enables the presently boxed rounds to be repacked with suitable trays. Such a procedure must be drafted with due regard to the problem areas outlined in this report and should be tested with instrumented trials before the live rounds are repacked. Assistance is available for suitable methods from staff at AMRL.

7. Acknowledgments

The assistance of FLTLT Nicholas Cram in coordinating activities at 1CAMD is appreciated.

8. References

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2. Billon, H. H. and Redman, L. (1993). *Electrostatic Testing of M52A3B1 Primers* (DSTO Technical Report DSTO-TR-0029). Aeronautical and Maritime Research Laboratory.

3. Royal Australian Navy *Protection of Explosives Facilities Against Electrostatic Hazards*. Chapter 3 in The RAN Explosives Ordnance Safety Manual ABR 862 Vol 1 Part 2 Section 7. (Restricted).

4. —, *Contract no. A87a/891 - M52A3B1 Characterisation*. For the U.K. Ministry of Defence. Thorn EMI (1981).

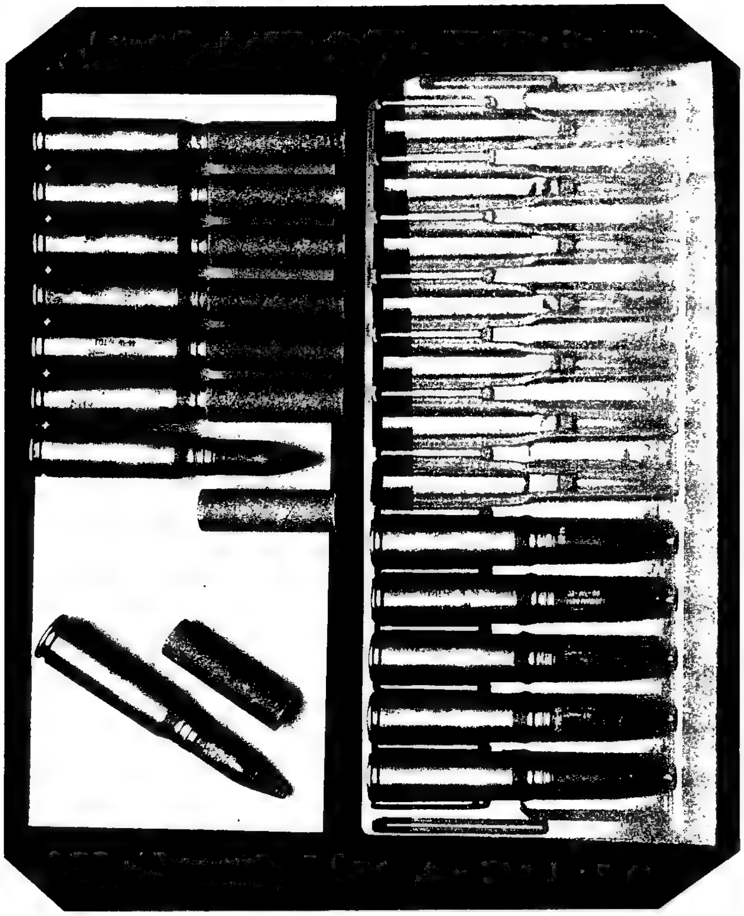

Figure 1: Comparison of the old packing method on the left with the new clear plastic tray on the right.

Figure 2: Handlers unloading ammunition by lifting a box over the stacked ammunition.

Figure 3: Handlers lifting ammunition from the stack on trays.

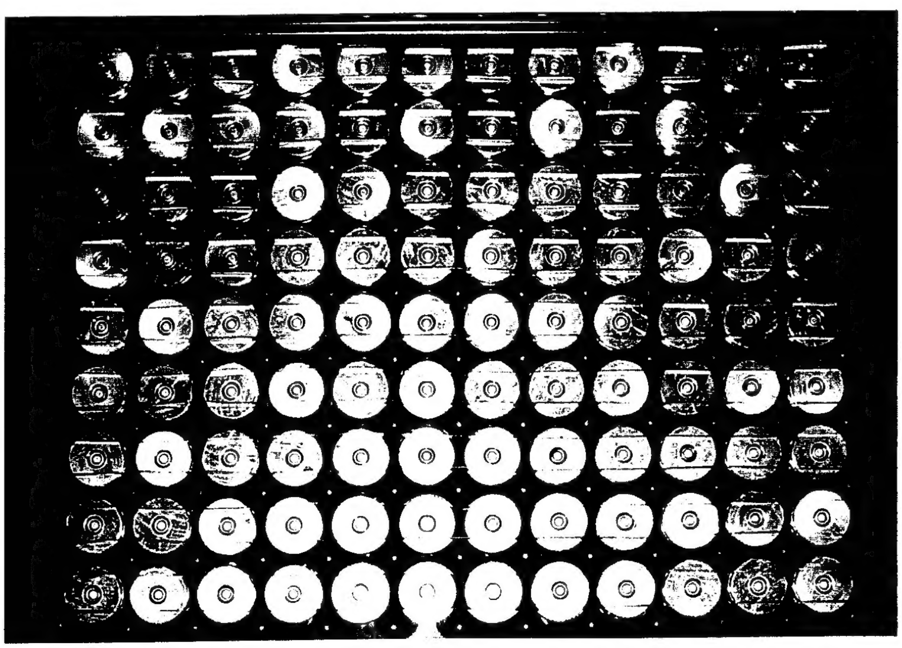

Figure 4: Array of ammunition used for the charging experiment. Only ammunition with its initiator facing the observer was considered. The round at top left is taken to be row 1, column 1.

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20. ABSTRACT

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